Modeling Boundary Layers and Air-Sea Interaction in the Coastal Ocean Using ROMS and COAMPS

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LONG-TERM GOALS

Circulation models used for ocean forecasting in coastal regions parameterize vertical mixing using a variety of turbulence closure hypotheses. The choice of closure scheme can lead to significant differences in simulated mesoscale flows. The long-term goal of this project is to critically compare observed and modeled vertical turbulent mixing processes and the exchanges of momentum and heat across the air-sea interface and evaluate which schemes perform better, in which coastal ocean settings, and for what reasons. This comparison is being undertaken by hind-casting the circulation in the CBLAST-Low observational region during the summers of 2002 and 2003. The analysis complements CBLAST observational studies by providing a quantitative assessment of the relative contributions of horizontal stirring and advection to the detailed, yet principally 1-dimensional, vertical heat budget analyses of air-sea flux and vertical mixing observations from the Martha's Vineyard Coastal Observatory (MVCO) during CBLAST-Low.

OBJECTIVES

The Regional Ocean Modeling System (ROMS), in conjunction with a high-resolution (3 km) COAMPS meteorological forecast, is being used to simulate circulation in the region encompassing the CBLAST-Low observational area. Observations from the 2002 and 2003 CBLAST Intensive Observing Periods enable evaluation of features of the model formulation and configuration that influence forecast capabilities of this geographically realistic coupled coastal ocean-atmosphere model in a region characterized by strong tidal forcing and strong diurnal heating, yet low to moderate wind-speeds.

APPROACH

A high degree of realism is employed in the configuration of the CBLAST-Low regional model in order to model the regional heat budget on diurnal to several day time scales, and spatial scales of order a few km. The model has 1 km grid spacing and bathymetry from the NGDC 3-arc-second Coastal Relief Model, active/passive inflow/outflow open boundaries incorporating a bi-monthly

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climatology of shelf circulation (Naimie et al. 1994) and boundary tidal forcing from a model of the western Atlantic (Luettich et al. 1992). Air-sea fluxes are computed using the bulk formulae of (Fairall et al. 2003) applied to model sea surface temperature and atmospheric boundary layer values predicted by 3-km resolution COAMPS forecasts for the 2002 and 2003 CBLAST observing periods.

Model validation is by comparison of the simulated heat budget to time series of sea temperature and air-sea flux observations acquired at moorings deployed in 2002 and 2003 by R. Weller (Hutto et al. 2003: Hutto et al. 2005). While a strict event-wise correspondence is not anticipated without data assimilation, the total heat content, mixed layer depth, rates of surface cooling and/or heating, and mixing and entrainment at the base of the mixed layer, should be reproduced and will likely prove sensitive to vertical turbulence closure.

The ROMS model configuration for the MVCO region is being undertaken by J. Wilkin. Turbulence closure option implementation is by J. Warner. Collaboration with R. He of Woods Hole Oceanographic Institution has adjusted the tidal open boundary conditions to better fit observations through a hybrid data assimilation procedure.

WORK COMPLETED

'Best-estimate' hindcasts of the 2002 CBLAST observational period have been completed using the Mellor-Yamada-2½ (MY25) (Mellor and Yamada 1982) turbulence closure scheme as a control case for vertical mixing option, and these results have been analyzed in detail with respect to in situ validation data from the CBLAST mooring program. Further simulations using the k-profile parameterization (KPP) (Large et al. 1994) and several options within the Generalized Length Scale scheme of (Umlauf and Burchard 2003: Warner et al. 2005) are also complete and await model skill and intercomparison analysis. A hybrid data assimilation system modeling system was developed to improve the simulation of barotropic tides and tidal dynamics on the southeast New England shelf by incorporating in-situ observations of tidal constituents analyzed from coastal sea level and bottom pressure gauges.

RESULTS

The 2002 model results show well recognized features of the regional summer circulation: warm temperatures and weak eastward flow in Nantucket Sound, cool tidally mixed waters and an associated anti-cyclonic flow encircling the Nantucket Shoals, and strong stratification south of Martha's Vineyard. Comparisons to satellite and in situ observations show the model simulates the major features of the temperature patterns that develop during summer 2002. The evolution of the summer heat budget is characterized by three regimes: Nantucket Sound heats rapidly in June and then maintains warm temperatures with little net air–sea heat flux; tidal mixing on the Nantucket Shoals maintains perpetually cool ocean temperatures despite significant air–sea heating; and mid-shelf south of Martha's Vineyard the surface waters warm steadily through July and August due to sustained air–sea heating with only modest cooling due to the mean circulation. In the environs of the Martha's Vineyard Coastal Observatory tidal eddy heat flux emanating from Nantucket Sound produces a bowl of warm water trapped against the coast and significant local variability in the net role of advection in the heat budget. A suite of idealized simulations with forcing dynamics restricted, in turn, to only one of winds, tides, or shelf-wide inflows shows that tidal dynamics dominate the regional circulation.

IMPACT/APPLICATIONS

Worldwide use of the ROMS model continues to grow, including applications involving the both east and west North American coasts and numerous sub-domains (New Jersey coast, Gulf of Maine, Hudson River, Long Island Sound, South Atlantic Bight, Gulf of California, CalCOFI, Gulf of Alaska and Bering Sea, and more), the incorporation of bio-optical, ecosystem, sediment, sea ice and ice-shelf sub-models into ROMS, and a rapidly growing user community in Europe and Asia. The CBLAST modeling system was used to illustrate the capabilites of ROMS as an operational forecast tool to assist in the deployment of moveable instrumentation, and as a synthesis tool to aid the interpretation of observations, in a series of lectures to students at International Summer Schools on ocean modeling in 2004 (Wilkin and Lanerolle 2005) and 2006 (http://lseet.univ-tln.fr/ecoleete/ecole25eng.html)

RELATED PROJECTS

This project complements the extensive ocean and atmosphere observational programs and related analyses and meteorological modeling studies that comprise ONR's CBLAST-Low DRI.

REFERENCES

Fairall, C. W., E. F. Bradley, J. E. Hare, A. A. Grachev, and J. Edson, 2003: Bulk Parameterization of Air–Sea Fluxes: Updates and Verification for the COARE Algorithm. *Journal of Climate*, **16**, 571-591.

Hutto, L., T. Farrar, and R. Weller, 2005: CBLAST 2003 Field Work Report. Woods Hole Oceanographic Institution, Tech. Rep. WHOI-2005-04, 136 pp.

Hutto, L., J. Lord, P. Bouchard, R. Weller, and M. Pritchard, 2003: SecNav/CBLAST 2002 field experiment deployment/recovery cruises and data report, F/V Nobska, September 4 and 9, 2002, mooring data June 19-September 9, 2002. Woods Hole Oceanographic Institution, WHOI-2003-07, 114 pp.

Large, W. G., J. C. McWilliams, and S. C. Doney, 1994: Oceanic vertical mixing: A review and a model with a nonlocal k-profile boundary layer parameterization. *Reviews of Geophysics*, **32**, 363-403.

Luettich, R. A., J. J. Westerink, and N. W. Scheffner, 1992: ADCIRC: An advanced three-dimensional circulation model for shelves, coasts, and estuaries. U.S. Army Engineer Waterways Experiment Station, Tech. Rep. DRP-92-6, 137 pp.

Mellor, G. L. and T. Yamada, 1982: Development of a Turbulence Closure Model for Geophysical Fluid Problems. *Reviews of Geophysics and Space Physics*, **20**, 851-875.

Naimie, C. E., J. W. Loder, and D. R. Lynch, 1994: Seasonal variation of the three-dimensional residual circulation on Georges Bank. *Journal of Geophysical Research*, **99,** C8, 15,967-15,989.
Umlauf, L. and H. Burchard, 2003: A generic length-scale equation for geophysical turbulence models. *Journal of Marine Research*, **61**, 235-265.

Warner, J. C., C. R. Sherwood, H. G. Arango, R. P. Signell, and B. Butman, 2005: Performance of four turbulence closure models implemented using a generic length scale method. *Ocean Modelling*, **8**, 81-113.

Wilkin, J. L. and L. Lanerolle, 2005: Ocean Forecast and Analysis Models for Coastal Observatories. *Ocean Weather Forecasting: An integrated view of oceanography*, E. P. Chassignet and J. Verron, Eds., Springer, 549-572.

PUBLICATIONS

Edson, J., T. Crawford, J. Crescenti, T. Farrar, N. Frew, G. Gerbi, C. Helmis, T. Hristov, D. Khelif, A. Jessup, H. Jonsson, M. Li, L. Mahrt, W. McGillis, A. Plueddemann, L. Shen, E. Skyllingstad, T. Stanton, P. Sullivan, J. Sun, J. Trowbridge, D. Vickers, S. Wang, Q. Wang, R. Weller, J. Wilkin, D. Yu, and C. Zappa, 2006: The Coupled Boundary Layers and Air-Sea Transfer Experiment in Low Winds (CBLAST-LOW). *Bulletin of the American Meteorological Society*, [in press].

He, R. and J. L. Wilkin, 2006: Barotropic tides on the southeast New England shelf: A view from a hybrid data assimilative modeling approach. *Journal of Geophysical Research*, **111,** C08002, doi:10.1029/2005JC003254, [published].

Wilkin, J. L. and L. Lanerolle, 2005: Ocean Forecast and Analysis Models for Coastal Observatories. *Ocean Weather Forecasting: An integrated view of oceanography*, E. P. Chassignet and J. Verron, Eds., Springer, 549-572, [published].

Wilkin, J. L., 2006: The summertime heat budget and circulation of southeast New England shelf waters. *Journal of Physical Oceanography*, [in press].